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FLUXES OF DISSOLVED ORGANIC CARBON AND NUTRIENTS LEACHING IN TOPOSEQUENT OF BUKIT DUA BELAS NATIONAL PARK, INDONESIA

[1]SYAIFUL ANWAR, [2]KUKUH MURTILAKSONO, [3]ARIEF HARTONO, [4]GILANG S PUTRA

[1,2,3]'epartment of Soil Science and Land Resource, Bogor Agricultural University, Indonesia
E-mail: syaianwar@yahoo.com

Abstract- The study of dissolved organic carbon (DOC) and nutrients leaching fluxes from soil profiles has important impacts to the quality of soils and the environment. This research was conducted in lowland secondary tropical forest of the Bukit Dua Belas National Park, Jambi Province, Indonesia. The research site was appropriated toposequent transect divided into three soil profiles in upper, middle, and lower slopes. The research results indicated that fluxes of DOC leaching of the lower slope was significantly higher compare to that of the middle and the upper slopes. Similarly, fluxes of nutrients leaching of AO soil horizon was higher compare to that of lower soil horizons. There were significant positive correlations between nitrate, phosphate, sulphate, chloride, and borate anions with calcium, magnesium, potassium, and ammonium cations. DOC leaching flux also has significant positive correlations with these ions.

Keywords- Lowland Secondary Tropical Forest, Flux. DOC, Cations, Anions.

I. INTRODUCTION

Dissolved organic carbon (DOC) is the most labile C fraction in biogeochemical cycling of soil surface [1] and it provides one of the largest pools of carbon in the ocean [2]. Meanwhile, DOC in the tropics is important because its contribution to the dynamic of soil organic matter and important soil elements such as plant nutrients. Leaching of DOC from the organic horizon of a forest floor is an important process involved in translocation and stabilization of organic matter in forest soils [3]. DOC leached from the O horizon appears to be an important carbon source into mineral soils, even in tropical regions while the DOC leaching contributed to eluviation of Al and Fe from the O horizon and their illuviation in the subsurface soil horizons [3, 4]. On the other hand, geomorphic properties, the role of past, present, and future land cover, anthropogenic impacts and other environmental change on any land such as a small coastal rivers and any spesific places exerts control on the quantity and flux of DOC in these systems [5].

Although many studies have shown that soil solution can be a reliable indicator of biogeochemical cycling in the forest ecosystem, the effects of litter manipulations on the fluxes of dissolved elements in gravitational soil solutions have rarely been investigated [6]. DOC as well as other ions are transported into lower horizons within soil profiles by the process of mineralization, leaching, or fixation. They are very mobile within the soil horizons and easily leached by water percolation [3]. The fluxes of C of the litter fall and soil respiration in tropical forest generally are greater than those in the temperate forests [7]. The vast majority of soils in the tropical forest are highly weathered and acidified because of the intensive leaching over long periods of time [8]. Furthermore, the leaching of basic cations such as Ca^{2+}, Mg^{2+}, K^+, Na^+ will lead to the soil acidification. The driving force of cations leaching are production of anions such as carbonic, nitrate, sulphate, phosphate, chloride, and borate. These anions will bond cations as ion pairs in soil solution. DOC and nutrients leaching by percolation water within the soil profiles will be influenced by its position in a toposequent transect. This research was aimed analyze DOC fluxes and nutrients leaching within soil profiles of appropriate toposequent transect in the Bukit Dua Belas National Park, Indonesia.

II. DETAIL OF EXPERIMENT

This research has been carried out during May 2014 – April 2016 in the Bukit Dua Belas National Park, Sarolangun District, Jambi, Indonesia. The research site was appropriated toposequent transect which is divided into three plots (upper, middle, and lower slopes) with two replication of toposequent transects, thus resulted in six plots of soil profiles on 60^o slope.

1.1. Soil Profiles Preparation and Instalation of Lysimeter

The six soil profiles and its horizons (AO, AB, and B) on the slope steepness were dug and described. The lysimeters were installed at those horisons (Figure 1). Installed lysimeters were connected into bottles (Tygon tubing) to collect leached water. In order to retard microorganism activity, a solution of 0.05 mgL^{-1} in $CuCl_2$ was dropped into the bottles.

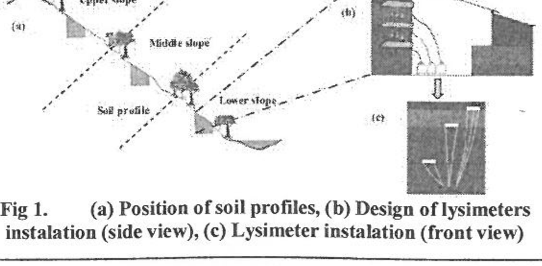

Fig 1. (a) Position of soil profiles, (b) Design of lysimeters instalation (side view), (c) Lysimeter instalation (front view)

1.2. Collection and storing of leached water samples

Leached water samples were collected periodically depends on the rainfall. The periodical volume of leached water samples were recorded. About 500 ml aliquod of the each leached water was sampled for laboratory analysis of DOC and nutrient ions. The samples were kept in a cooler to maintain their quality before laboratory analysis.

1.3. Analysis of leached water samples

Method of NPOC (Non Purgeable Organic Carbon) has applied to measure the DOC concentration. Microfibre filter of Whatman GF/F 0.45 µm pore size was used to separate DOC from POC (Particulate Organic Carbon). The DOC in the filtrate was measured with TOC-VCPH SHIMADZU through combustion at 680°C to convert organic carbon to CO_2 gas then detected by sensor of NDIR (non-dispersive infrared) to measure the concentration of the DOC. Meanwhile, the concentration of nutrients (cations and anions) were measured by atomic absorption spectrophotometrics (AAS) method. The ions which were measured include PO_4^{3-}, NO_3^-, HCO_3^-, SO_4^{2-}, Cl^-, BO_3^- anions, and Ca^{2+}, Mg^{2+}, K^+, NH_4^+ cations.

2.4. Fluxes of DOC and nutrients leaching

The fluxes of DOC from each horizon were calculated by multiplying the water fluxes by the DOC concentrations in throughfall and soil solutions. The water fluxes of throughfall were measured using precipitation collectors, whereas those of soil water percolating at average depths of 5, 15, and 30 cm were estimated by applying Darcy's law [9] to the unsaturated hydraulic conductivity and the gradient of the hydraulic heads at the each depth. Total of solutes (DOC and ions) that eluviated within soil profiles was calculated as follows:

$\Sigma TOS = V \cdot C$

where, Σ TOS = total of solute (DOC and nutrient ions) (mg); V = volume of percolated water (L); C = concentration of solute (mgL^{-1}). Flux of water was calculated as follows:

$J_w = V / A / \Delta t$

where, J_w = flux of water ($cmday^{-1}$); V = volume of percolated water (L); A = area of lysimeter (cm^2); Δt = periods of sampling (days). Flux of DOC and nutrient ions was determined based on total transport (bulk transport) of DOC and nutrient ions which is transported within waterflow in soil pores (J_{lc}) by equation:

$J_{lc} = J_w \cdot C_l$

where, J_{lc} = fluks of solute tranport ($mgcm^{-2}day^{-1}$); J_w = flux of water ($cmday^{-1}$); C_l = concentration of solute (mgL^{-1}).

III. RESULTS AND DISCUSSION

Soil order in the research site is classified as Ultisols (USDA) or Acrisols (FAO). The studied soil texture generally is sandy clay loam (50 – 70% of sand) within soil profiles, 0.13 – 0.15% of organic carbon content in AO horison, and 3.89 – 9.87 $cmol_{(+)}kg^{-1}$ of CEC. Acrisols are having an argilic horizon starting at ≤ 100 cm from the soil surface, a clay CEC (by 1 M NH_4OAc, pH 7) less than 24 $cmol_{(+)}$ kg^{-1} in some part of the argilic horizon within ≤ 50 cm, and an effective base saturation <50% [10]. Land use of the research site is secondary forest and dominated by Eusideroxylon zwageri, Shorea sp., Koompassia excelsa, Dyera costulata, Daemonorops draco, Agathis sp., and rattan (Calamus sp.).

The research results (Table 1) showed that the total of annual DOC fluxes in the soil profiles from the lower slope was the highest (114.13 $kgha^{-1}$ $year^{-1}$ from AO, and 15.03 $kgha^{-1}year^{-1}$ from AB horizons), while that from the upper slope was the lowest (56.41 $kgha^{-1}year^{-1}$ from AO, 5.20 $kgha^{-1}year^{-1}$ from AB, and 4.96 $kgha^{-1}year^{-1}$ from B horizons). Meanwhile profile wisely, the annual DOC fluxes of AO soil horizon was higher (56.41, 61.68, and 114.13 $kgha^{-1}year^{-1}$, respectively from upper, middle and lower slopes) and significantly different compared to the flux of AB (5.20, 9.72, and 15.03 $kgha^{-1}year^{-1}$, respectively from upper, middle and lower slopes) and that of B (4.96 and 2.81 $kgha^{-1}year^{-1}$ from upper and middle slopes) horizons. The higher the volume of the percolated (leached) water resulted in the lower concentration of eluviated DOC during dry season (June-October), but the total DOC was higher during the rainy season (November-April).

Table 1. The annual flux and periodically amount of DOC based on soil horizons and soil profiles position of the toposequent

Time of sampling	Upper slope			Middle slope			Lower slope	
	AO	AB	B	AO	AB	B	AO	AB
	$kgha^{-1}$							
June, 12, 2014	2.97	0.24	0.69	1.57	1.83	0.25	26.56	0.05
August, 26, 2014	8.22	0.19	0.00	1.48	0.00	0.00	14.63	0.56
October, 06, 2014	5.40	0.00	0.00	4.24	0.00	0.00	0.37	0.00
November, 29, 2014	13.93	1.01	1.61	24.01	0.58	0.00	21.24	1.94
January, 14, 2015	7.55	1.14	1.03	8.39	0.53	0.22	17.10	0.77
March, 18, 2015	10.84	0.83	0.10	8.49	0.15	0.14	24.94	0.10
April, 30, 2015	5.38	0.72	3.61	2.02	0.41	0.07	26.80	1.69
June, 14, 2015	4.47	0.75	0.44	1.80	0.25	0.21	20.05	4.98
August, 05, 2015	3.86	0.09	0.00	4.84	0.11	0.00	2.55	0.27
October, 27, 2015	2.05	0.16	0.00	0.70	0.10	0.00	1.09	0.25
February, 04, 2016	30.73	4.36	1.76	27.86	9.98	3.91	31.66	10.76
April, 28, 2016	9.37	0.17	0.00	29.16	4.09	0.42	25.01	6.55
Total flux ($kgha^{-1}$)	104.78	9.66	9.22	114.57	18.05	5.21	212.00	27.92
Total flux ($kgha^{-1}year^{-1}$)	56.41	5.20	4.96	61.68	9.72	2.81	114.13	15.03

The highest fluxes was from AO soil horizon of the lower slope position, because of the high concentration of DOC particularly in the upper (O or AO) soil horizon during dry season due to accumulation of organic matter decomposition [11, 12]. Among slopes, the highest DOC was accumulated from AO soil horizon of the lower slope during rainy season. Meanwhile in the soil profile, the highest DOC flux was from the upper soil horizon and decreasing in lower soil horizon which is in accordance with [13]. In addition to precipitation effect, DOC flux is also affected by carbon content particularly lignin of litter and humus accumulation [3, 12, 14].

The research results (Table 2) showed that the highest total flux of anionic leaching was in nitrate ion (NO_3^-) which was equal to 130.92 kgha^{-1} of AO and 20.78 kgha^{-1} of AB horizons of the lower slope soil profile. Nitrate ion has the potential to bring the soil major cations as its ion-pairs, because it is highly mobile in soil. As shown by the Pearson-correlation matrix in Table 3, total flux of nitrate leaching (April 30, 2015 – October 27, 2015; up to recent available data) has a positive correlative relationship (p-value $< \alpha$, $\alpha = 0.05$; pearson-correlation value ≈ 1) with the fluxes of basic cations leaching (NH_4^+, 0.78; Ca^{2+}, 0.82; Mg^{2+}, 0.86; and K^+, 0.59). Meanwhile, the lowest total fluxes of anion was in phosphate ion (PO_4^{3-}) leaching, which was in a range of 0.37–0.68 kgha^{-1} from AO, 0.09–0.11 kgha^{-1} from AB, and 0.05–0.06 kgha^{-1} from B horizons. Nevertheless, the dynamics fluxes of phosphate ion has the potential to increase the total fluxes leaching of the soil cations as its ion-pairs as well, as shown by their Pearson-correlation (Table 3). The total phosphate ion fluxes also has a positive correlative relationship (p-value $< \alpha$, $\alpha = 0.05$; Pearson-correlation value ≈ 1) with the fluxes of basic cations leaching (NH_4^+, 0.93; Ca^{2+}, 0.96; Mg^{2+}, 0.98; and K^+, 0.83). Similar significant positive correlative relationships of the cationic leaching fluxes were also found with the leaching fluxes of sulphate, chloride, and borate anions; but not with the leaching fluxes of bicarbonate anion.

The fluxes of DOC leaching has significantly positive correlative relationship (p-value $< \alpha$, $\alpha = 0.05$; Pearson-correlation value ≈ 1) with the leaching fluxes anions except bicarbonate, and with the leaching fluxes of all cations. These positive correlative relationship could indicate that an increase in the DOC leaching fluxes will increase the leaching of nutrients leading to a degradation of soil fertility due loss of the available soil nutrients [15].

Table 2. The total annual fluxes of nutrient ions based on soil horizons and soil profiles position of the toposequent (April 30, 2015– October 27, 2015)

Ions species	Upper slope			Middle slope			Lower slope	
	AO	AB	B	AO	AB	B	AO	AB
	kgha^{-1}							
Anions								
PO_4^{3-}	0.51	0.11	0.05	0.37	0.09	0.06	0.68	0.09
NO_3^-	58.81	12.40	29.04	46.07	11.68	4.60	130.92	20.78
HCO_3^-	10.34	7.88	3.21	1.44	6.45	0.56	0.00	1.42
SO_4^{2-}	30.75	6.36	7.95	13.85	3.36	3.26	61.61	14.54
Cl^-	31.30	8.62	7.50	20.64	7.98	1.72	51.90	10.61
BO_3^-	4.05	0.34	0.11	1.74	0.44	0.03	5.43	0.78
Cations								
Ca^{2+}	6.42	0.85	0.38	3.29	0.58	0.08	5.63	1.05
Mg^{2+}	5.41	0.41	0.04	2.52	0.36	0.04	5.39	0.74
K^+	62.91	5.96	0.34	36.37	5.52	0.09	31.01	4.52
NH_4^+	14.08	1.80	1.04	5.55	1.44	0.04	10.75	1.07

Table 3. Pearson-correlation of DOC and nutrient ions leaching fluxes (April 30, 2015– October 27, 2015)

	DOC	PO_4^{3-}	NO_3^-	HCO_3^-	SO_4^{2-}	Cl^-	BO_3^-
DOC	-	0.88	0.98	-0.29	0.99	0.96	0.91
Ca^{2+}	0.76	0.96	0.82	0.19	0.84	0.91	0.96
Mg^{2+}	0.81	0.98	0.86	0.13	0.88	0.94	0.98
K^+	0.49	0.83	0.59	0.36	0.59	0.71	0.79
NH_4^+	0.71	0.93	0.78	0.30	0.80	0.87	0.93

CONCLUSION

The research of leaching fluxes of DOC and nutrients within soil profiles along toposequent transect in Bukit Dua Belas National Park, Indonesia, can be conclude as the following:

a. The highest of total annual DOC fluxes in the soil profiles was resulted from the lower slope, while the lowest of annual DOC fluxes in the soil profiles was resulted from the upper slope. Meanwhile, the total annual DOC fluxes from AO soil horizon was higher and significantly different compared to that of AB and B horizons.

b. The higher the volume of the percolated (leached) water resulted in the lower concentration of eluviated DOC. The total of DOC, however, was higher during the rainy season. The highest fluxes was from AO soil horizon of the lower slope.

c. The highest total flux of anionic leaching was in nitrate anion, while the lowest was in phosphate anion. Pearson correlation of anionic and cationic ions indicated that there were significant positive correlative relationships of cations with nitrate, phosphate, sulphate, chloride, and borate anions, but not with bicarbonate anion.

d. The fluxes of DOC leaching has significantly positive correlative relationshipwith the leaching fluxes cations and anions, except bicarbonate.

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